22. (Amended) The method of claim 12 wherein the lens elements have a residual field curvature so as to vary locally in magnification, the lenses providing an angular resolution increasing toward a center of a viewing field and a spatial resolution increasing at peripheral angular locations.

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In the Drawings:

Changes to the drawings are indicated in red on the attached copies of the as-filed formal drawings. These drawing corrections are also noted below in the accompanying Remarks.

In the Specification:

Please make the changes to the specification set forth in the marked-up and clean versions below.

REMARKS

Administrative Overview

The Office action rejects claims 1-5 and 7-11 under 35 U.S.C. § 102(a) as anticipated by Morton (U.S. Patent No. 5,276,478). Additionally, claims 6 and 12-23 are rejected under 35 U.S.C. § 103(a) as obvious in light of Morton. Further, the Examiner objects to informalities in the specification and drawings. The Examiner also discusses the status of a reference submitted with the previous Information Disclosure Statement.

Formal Objections

In the Office action mailed on March 13, 2003, the Examiner objected to the drawings and specification due to various enumerated inconsistencies. With respect to reference numerals or letters found in the specification but purportedly not in the drawings, we respond as follows. Applicants amend Fig. 2 to include the variables "w" and "W." Reference numeral 200 is added to Fig. 6 in lieu of reference numeral 520. Reference numeral 355 is added to Fig. 12 in lieu of reference numeral 90. Reference numeral 80 is added to Fig. 12 in lieu of reference numeral 350. Reference numeral 355 is added to Fig. 13 in lieu of reference numeral 90. Reference numeral 350 is added to Fig. 19 in lieu of reference numeral 360.

With respect to reference numerals found in the drawings but purportedly not in the specification, we respond as follows. Concerning Fig. 8B, the amendment to the specification corrects a typographical error, so that in the last sentence on page 20, Pixel 225 is replaced with Pixel 225'. In Fig. 15, the amendment to the specification corrects a typographical error, so that

in line 8 on page 22, "adjacent substrate 380." is replaced with "adjacent substrate 385." With regard to Fig. 16, the point K in the figure is included as shown in the marked-up and clean copies of the specification, with the addition of "at point K" on page 22. Reference numeral 620 denotes the conjoint effect represented in Fig. 22C, and is included as shown in the marked-up and clean copies of the specification on page 28. Concerning Fig. 24B, the amendment to the specification corrects a typographical error, so that on page 32 at line 7, P' is replaced with P''.

Regarding the other typographical errors and inconsistencies cited by the Examiner in the specification, we respond as follows. Concerning the discussion of effective magnification on page 20 at line 3, Applicants replace "19X" with "17X" as suggested by the Examiner. Additionally, on page 42 at lines 5 and 6, "FIG. 24A" is replaced with "FIG. 23A" as suggested by the Examiner. Apart from the amendments discussed above and in this paragraph, various typographical errors that were not cited by the Examiner are also corrected in the marked-up and clean copies of the amendment to the specification transmitted herewith.

Information Disclosure Statement

The Examiner points out that the German patent DE 43 01 477 was not considered, although it has been placed in the application file, because of the lack of a concise explanation of its relevance. Applicants received this reference, without a translation, as part of the search report in the corresponding PCT application. The reference was characterized as an "A" reference on the PCT/ISA/210 form indicating that it was a "document defining the general state of the art which is not considered to be of particular relevance." In light of this, Applicants respectfully request that the Examiner consider this reference along with the accompanying arguments provided below.

Substantive Rejections

The Examiner rejected claims 1-5 and 7-11 under 35 U.S.C. § 102(a) as anticipated by Morton. Additionally, claims 6 and 12-23 stand rejected under 35 U.S.C. § 103(a) as obvious in light of Morton.

The lens array of claim 1 requires "an array of lens elements having a backplane for reproducing an image located at the backplane" such that the lenses are "reproducing visual information from the backplane to a *finite conjugate region in free space*." Similarly, claim 12

teaches a method having "the lens array reproducing visual information to *a finite conjugate region in free space*." For the reasons set forth below, we submit that the use of finite conjugates in general and, in particular, the reproduction of visual information to a finite conjugate region in free space are not disclosed or even suggested by Morton.

Generally, conjugate points are a pair of points that share an invariable relationship to each other such as, for example, the object and image points of a lens system. In this example, both points are positioned, in relation to a lens, such that light emitted from either point converges to and then diverges from the other. (See Figures 2 and 5 of the present application for examples.) Finite conjugates differ from infinite conjugates in that one or both points are not positioned or focused at infinity.

Morton describes lenticular technology relating to image line sets, specific methods of printing these line sets, and the use of such line sets in combination with a lenticular overlay. Morton uses a "conventional lenticular lens assembly or overlay" with "half cylindrical lenses forming a lenticular overlay." (See column 3, line 31-32 and column 1, line 63-65.) In Morton, the half-cylindrical lenses of the lenticular array act as collimators along a transverse axis. These lenses do not have a refractive action (other than thickness) in the longitudinal direction. At column 1, lines 44-47, the patentees note: "Each lenticule is associated with a plurality of image lines or an image line set and the viewer is supposed to see only one line image (or view slice) of each set with each eye for each lenticule."

Conventionally, this effect of seeing only one line image is reliably obtained only by locating the backplane substantial at the focal length of the lens array. This induces the lenses to act as collimators, and therefore produces an optical system having *infinite conjugates*. Each lens of the array then magnifies one line image as taught by Morton, resulting in the image mapping to one or both eyes of a viewer positioned at the requisite viewing distance (see Figs. 1 and 6 of Morton).

The impression of depth, in applications such as that achieved by the collimating array of Morton, is produced by the angular variability of the image. Angular variability can provide both stereoscopy (differing images to the right and left eyes) and parallax (differing views as a function of eye position). This perception of depth occurs in Morton through the uninterrupted

rays containing image line data directly passing to the eyes of a viewer without any intervening image formation along the path to the eye.

Reproducing visual information at a "*finite conjugate region* in *free space*" as claimed and illustrated in the present application (see, e.g., Figs. 2 through 6), is very different. Whereas in Morton the lenticular array directs information directly into the eyes of an observer without a real image forming at an intervening conjugate point or region in free space, the present claims require just this effect. As explained in the specification:

> To provide stereoscopic depth cues, the invention is configured to have nonunitary magnification. Any overlap of the aerial micro images allows a given conjugate point in free space to be traversed by more than one source. The visual information apparent at a given point in free space therefore depends upon a viewer's position, and the rate with which the information varies with a change in viewer position represents the angular resolution. This allows for simulated animation and stereographic three-dimensional display. (Page 12, lines 15-21.)

As shown in Figures 1 and 6 of Morton, no such point in free space is contemplated; only a conventional lenticular display using specially printed image line sets is disclosed.

In short, the concept of using *finite conjugates in free space*, central to claim 1 and 12, is neither disclosed nor suggested by — indeed, is fundamentally at odds with — the conventional lenticular array used in Morton. Because claims 1 and 12 are novel thereover, it follows that the remaining claims are novel as well.

In light of the foregoing, we submit that all claims are now in condition for allowance.

Respectfully submitted,

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Reg. No. 33,497

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MARKED-UP VERSION OF AMENDED CLAIMS

10. (Amended) The lens array of claim 1 wherein the lens elements have a residual field curvature so as to vary locally in magnification, the lenses providing an angular resolution increasing toward a center of a viewing field and a spatial resolution ~~at~~ increasing at peripheral angular locations.

22. (Amended) The method of claim 12 wherein the lens elements have a residual field curvature so as to vary locally in magnification, the lenses providing an angular resolution increasing toward a center of a viewing field and a spatial resolution ~~at~~ increasing at peripheral angular locations.

MARKED-UP VERSION OF AMENDMENTS TO THE SPECIFICATION

Please amend the paragraph beginning at page 2, line 17 as follows:

Traditional lenticular lens arrays have been designed with relatively little attention to the depth at which each lens focuses light in front of the lens array. Two configurations commonly exist, each created based on a conjecture as to how light should ~~exist~~ exit the lens array. For various reasons, existing lens array systems produce suboptimal three-dimensional images.

Please amend the paragraph beginning at page 18, line 5 as follows:

Only a static, monochromatic, matte object point, located ~~precicely~~precisely at the virtual source point in free space, will produce a constant color and intensity across the viewing range of the image. Accordingly, light directed at various angles through point Z' from a plurality of microlenses may be graphically differentiated to the extent allowed by the angular resolution. In addition to facilitating encoding of distinct stereoimages, this angular resolution may be used, for example, to represent animation, or changes in surface qualities such as color, tone, transparency, or specularity. In other words, as the user moves and the right and left eyes intercept rays from different portions of the graphic image at backplane 116, the user perceives different (but stereoscopically matched) images that collectively represent the animation or other effect. The angular variation can also represent parallactic object geometries that will often depart from the projective locus identified by the neighboring lenses. In three-dimensional imaging, the virtual light source often appears to emanate from a location different from that suggested by the parallactic geometry of the represented object. This circumstance is indicated in FIG. 5, in that converged real image is shown as linear in section, while the simulated object is shown as convex.

Please amend the paragraph beginning at page 19, line 20 as follows:

FIG. 7 depicts the effect of chromatic aberration on magnification. Many simple lens systems of the type commonly used in arrays exhibit axial chromatic aberration. In some

embodiments of the invention, this can produce an effective variation of magnification due to differences in the frequency of the converged light. Thus, blue conjugate field 220, green conjugate field 230, and red conjugate field 240 dictate effective magnifications of 13X, 15X, and ~~19X~~ 17X for blue, green and red light, respectively. Image-processing calculations may therefore be made based upon a knowledge of these differing magnifications, and the intermodulation of spatial and angular resolutions may also be varied according the wavelength(s) of light being reproduced.

Please amend the paragraph beginning at page 20, line 7 as follows:

FIG. 8A shows a single hexagonal lens aperture and its associated microimage. The microimage need not have the same shape as the lens aperture. As indicated in FIG. 2, the lens elements define a common focal plane 120 and focal length F. Graphic image plane 116 is located at a distance greater than F. As shown in the figure, a microimage 125 (see FIG. 2) need not be continuous-tone, but may instead be comprised of a contiguous set of quantized image elements in the form of pixels, one of which is representatively indicated at 225. The number of pixels accessible to a given lens element 110 depends on the lens design. In the figure, lens element 110 is convex with a hexagonal emission aperture (see FIG. 1). Light from pixels accessible to lens element 110 is collected and directed toward a finite conjugate in free space. As shown in FIG. 8B, the conjugate fields of lenses 110 within the same vicinity may overlap at a location ahead of the array; that is, the magnified image 125' of microimage 125 produced by lens 110_1 can overlap with the magnified image produced by neighboring lens 110_2. Pixel ~~225~~ 225' is increased in apparent size as a direct function of the magnification factor M.

Please amend the paragraph beginning at page 22, line 5 as follows:

FIG. 15 shows a lens 300 associated with a layered system of graphic material 360 that includes an outer dioramic microimage 365, a transparent region 370, and an inner dioramic microimage 375. Microimage 365 is carried on a transparent substrate 380, and microimage 375 is carried on an adjacent transparent substrate ~~380~~385. Because of this layered structure, the

system ~~cam~~ can produce virtual light sources at distinctly separate locations as shown in FIG. 16. Graphic material at point J on microimage 365 appears to emanate from point J' behind the array, while graphic material at point K on microimage 375 optically emulates a location K' ahead of the lens 300. Thus, layered graphic material can simulate diverse virtual source locations.

Please amend the paragraph beginning at page 25, line 17 as follows:

FIGS. 20 and 21 illustrate the manner in which an array 500 of lenses 450 (see FIG. 18) interacts with the visual system of an observer O. This configuration does not fully correct for field curvature, but instead projects a finite conjugate field to a series of curved quadratic surfaces 510 in free space. The quadratic surface indicated at 515 represents the conjugate field of a given lens 450 within the array 500. The overlapping quadratic field 520 represents a contributing finite conjugate field produced by a neighboring lens 450. In this case, the eyes will tend to accommodate to a virtual emission that diminishes in axial distance from the lens array 500 as the viewer's position departs from alignment with the optical axis of the observed microlens. This accommodation is suggested in FIG. 21 by the two ~~postions~~positions of the right (R) and left (L) eyes of the observer O shown at two positions in the viewing field.

Please amend the paragraph beginning at page 26, line 21 as follows:

As in the case of axial chromatic aberration, lenses having residual field curvatures produce varied magnifications in the image-processing phase. A lens having a residual field curvature effectively varies locally in magnification, providing an angular resolution increasing toward the center of the viewing field and a spatial resolution ~~at [typo]~~ increasing at peripheral angular locations. While this arrangement causes the resolution of the viewed image to be somewhat indeterminate according to conventional quantification methods, the combined effects of the aerial mosaic conjugate field and varied magnification assist in the visual decorrelation of the images from the regular structure of the lens array 500. The failure to decorrelate the image from the display structure in many prior stereoscopic displays has often yielded a quantized, pixelated appearance that has detracted from the illusion of depth.

Please amend the paragraph continuing on page 28, as follows:

This is shown schematically in FIGS. 22A-22C. An array of lenses corrected according to the design of FIG. 18 can usefully resolve several pixels within an aperture of 0.5mm. FIG. 22A shows a first observed mosaic finite conjugate field 600 (produced by lenses 450 with hexagonal apertures) having a lateral resolution approximately twice the lens pitch. FIG. 22B illustrates a slightly displaced conjugate field 610 reproducing the same visual material but having a local resolution approximately three times the microlens pitch. This is representative of conditions encountered using devices formed according to the invention, in which the perceived image structure differs for the right and left eyes. FIG. 22C schematically represents the conjoint graphic effect 620 represented to the observer's retinas. This viewing condition differs greatly from, for example, that created by a conventional two-dimensional LCD panel. For a two-dimensional LCD display, the two eyes fix on a common image structure, and the black background grid surrounding the pixels is often discernible. In FIGS. 22A through 22C, a small area of an autostereoscopic image according to the invention is shown including seven lenses; each of the seven lenses includes a plurality of pixels. When the eyes converge on a stereoscopic image, the eyes angle inward to adjust to the object's parallax. The conjoint effect 620 is represented in FIG. 22C, where the best image is obtained not by visually aligning the pattern of the lens outline, which is in practice difficult to visually resolve, but instead by responding to the graphic and optical characteristics of the projected pixels.

Please amend the paragraph beginning at page 32, line 4 as follows:

The benefits of the invention may be obtained using lens designs other than those shown in FIGS. 18 and 19. For example, FIG. 23A shows gradient-index (GRIN) ~~limaging~~ imaginglens 700 having a radial index gradient across the diameter α. FIG. 24B shows a point P imaged by such a lens to a conjugate finite point ~~P'~~ P'' in a nonunitary magnification. FIG. 24A shows an elongate GRIN lens 710 yielding a noninverted image. Similar noninverting rod lenses are commonly used in reimaging scanners, but may also be used to rectify pseudoscopy in autostereoscopic integral imaging systems.